Radar Backscattering Cross-Section Monitoring in the Simpson Desert of Australia for the TOPEX/Poseidon NASA Radar Altimeter

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1.0 Introduction

The radar surface backscattering coefficient, σ^0, is a measure, in dB, of surface radar reflectivity. It is sometimes referred to as sigma-naught or sigma-zero. In the processing of open-ocean NASA radar altimeter data, σ^0 values are used to compute surface wind speeds, where higher σ^0 are indicative of lower wind speeds, and vice-versa. The derived wind speeds are, in turn, used in conjunction with significant waveheights to calculate electromagnetic (EM) biases.

Values for σ^0 are computed separately for the Ku- and C-Band frequencies. The basic altimeter measurement pertaining to σ^0 is automatic gain control (AGC) which has a least-significant-bit (LSB) of 0.25 dB, and is at a measurement rate of twenty-per-frame; a frame is approximately one second in duration. During ground processing, AGC for each of the two frequencies is instrument-temperature-corrected and then compressed to one-per-frame. Each is corrected for the effects of off-nadir pointing and waveheight-induced waveform shape changes, and then a frequency-dependent post-launch calibration correction, discussed later, is applied. These corrected AGC values are converted to σ^0. The final steps in computing the σ^0 are to apply a correction for the effects of the intervening atmosphere and to normalize the σ^0 values to a reference orbital height.

The objective of this study is to monitor the cycle-to-cycle stability of the computed σ^0 to discern any temporal changes. The monitoring area, to be fully effective, needs to have year-round invariable surface reflectivity, to have subdued topography to permit altimeter lock-on, and to be sufficiently large in area to enable the averaging of ten or more successive frames of σ^0 values.

2.0 Simpson Desert as a Monitoring Area

We have examined TOPEX NASA Altimeter σ^0 measurement data in desert areas of Africa, North America and Australia. Our search has focused on deserts as they are physiographically and climatologically most likely to meet the monitoring criteria.

The most promising area we have observed for σ^0 monitoring is the Simpson Desert of east-central Australia. The Simpson Desert is the driest desert of Australia, and contains neither surface water nor habitation. It slopes very gently (70 cm / km, based on the altimeter range measurements) to the south-east toward the lowest spot in Australia, the dry salt-encrusted Lake Eyre. More than a thousand low (20-35 m height) parallel sand dunes in the desert extend for distances of up to 200 km. The stable dunes are about 500 m apart, and they extend from the north-northwest to the south-southeast (Vessels, 1992); the dune lines are roughly parallel to the descending TOPEX / POSEIDON groundtrack through the desert. This desert has a total area of about 150,000 square kilometers, and the average rainfall is less than 10 cm per year. Some years, it doesn't rain at all.

The Simpson Desert area is located in the vicinity of 250S latitude and 1370E longitude. TOPEX / POSEIDON Pass 088 traverses the Simpson Desert, in a north-west-to-southeast direction, as depicted in Figure 1. The pass 088 groundtrack recurs, within a narrow 2 km band, every 9.92 days. To the altimeter, the dunes are akin to high seastate in the open ocean.

3.0 Simpson Desert σ^0 Data

This study considers TOPEX altimeter data for pass 088 from Cycles 10-19, 21-30, 32-40, 42-54, 56-64, 66 and 68-75. The initial nine cycles are not used due to non-optimum spacecraft pointing control during those cycles. Also, during five other Cycles (20, 31, 41, 55 and 65), the TOPEX altimeter was in Idle Mode while the CNES altimeter was operating; during Cycle 67 the data were not valid due to a spacecraft maneuver. The σ^0 patterns for pass 088 across the Simpson Desert are very consistent, cycle-to-cycle. This consistency, together with the cycle-to-cycle repeatability of altimeter-derived sea surface heights and significant waveheight values, lend credence that the altimeter performance is well-behaved in this desert area.

3.1 Calibration Corrections to AGC

The NASA altimeter has an internal calibration mode for range and for AGC. Based on analysis of the twice-daily calibrations, NASA altimeter engineers at Wallops Flight Facility (WFF) periodically provide the TOPEX / POSEIDON Project with post-launch calibration correction values for ground-processing.

To date, WFF has provided the Project with Ku and C-Band AGC calibration corrections on three occasions: just prior to Cycle 48, just prior to Cycle 56, and again just prior to Cycle 76. For the initial correction set, there was a time lag in providing the values, due to two factors: a) the correction values being small, and b) the gaining of confidence that the calibrations were indeed applicable to

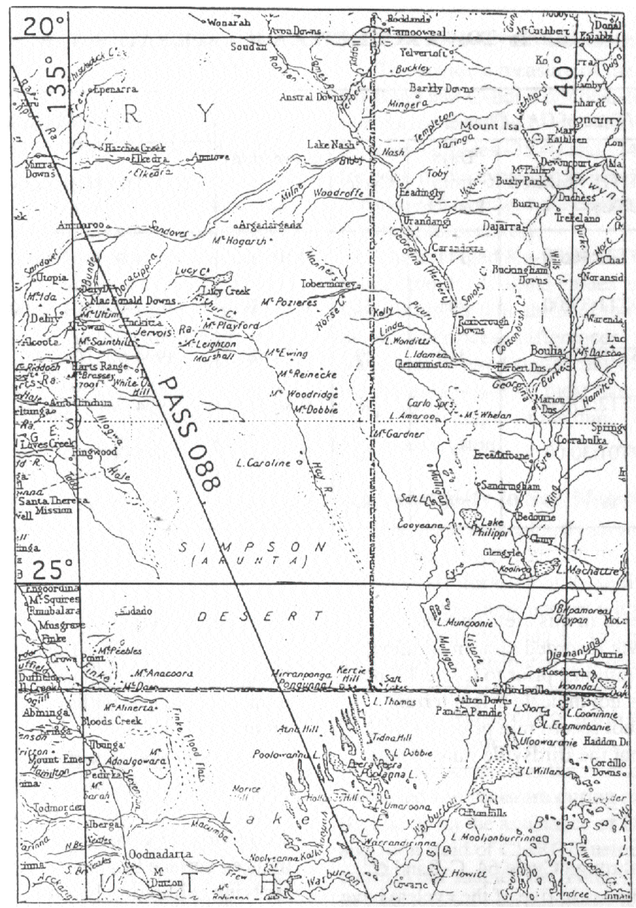

Figure 1 - Pass 88 Groundtrack Across the Simpson Desert

the tracking data.

The third correction set has been derived from over two years of data to determine improved corrections. Since some corrections have been applied in the (I)GDR processing, the new correction minus any applied correction must be added to the IGDR and GDR data. (These are technically AGC corrections, but there is a one-to-one relationship of AGC change to σ^0 change.). Table 1 lists the dates, times and values for the AGC corrections based on the revised calibrations, and lists the dates, times and values for the corrections applied to the IGDR and GDR data sets. Each of the corrections listed in Table 1 is the total applicable correction from that date and time.

For this Simpson Desert σ^0 analysis, the latest set of corrections have been locally applied to the data.

3.2 Cycle-to-Cycle Consistency

To provide a measure of the cycle-to-cycle Ku-Band and C-Band σ^0 consistency, after calibration corrections, the 21 one-frame-average σ^0 values between latitudes -25.40 and -24.40 were averaged for each of the cycles. The Ku-Band and C-Band per-cycle σ^0 averages are depicted in Figure 2 and Figure 3, respectively.

The averaged Ku-Band and C-Band σ^0 have similar trends. C-Band values are approximately four dB higher than Ku-Band, similar to their over-ocean differences. The altimeter waveform-derived significant waveheight (SWH) for this area is 6-8 m,

Freq	Date/Time of CAL Change			Date/Time First Applied to (I)GDR		
	YYYY-DDDTHH:MM:SS (UTC)	Cycle	Current Corrections	YYYY-DDDTHH:MM:SS (UTC)	Cycle	Applied Corrections
Ku	1992-238T00:00:00	-	-0.15 dB	1994-002T04:29:00	48	0.25 dB
Ku	1992-346T11:26:23	9	0 dB	1994-081T12:17:00	56	0.30 dB
Ku	1993-099T11:08:41	21	0.10 dB	1994-279T19:47:31	76	0.45 dB
Ku	1993-139T03:02:48	25	0.15 dB			
Ku	1993-208T12:52:25	32	0.20 dB			
Ku	1993-337T10:33:15	45	0.25 dB			
Ku	1994-022T00:25:50	50	0.30 dB			
Ku	1994-081T12:17:00	56	0.35 dB			
Ku	1994-180T16:02:15	66	0.40 dB			
Ku	1994-220T07:56:20	70	0.45 dB			
C320	1993-099T11:08:41	21	0.10 dB	1994-002T04:29:00	48	0.10 dB
C320	1993-208T12:52:25	32	0.15 dB	1994-081T12:17:00	56	0.15 dB
C320	1993-337T10:33:15	45	0.20 dB	1994-279T19:47:31	76	0.35 dB
C320	1994-022T00:25:50	50	0.25 dB			
C320	1994-111T06:12:34	59	0.30 dB			
C320	1994-180T16:02:15	66	0.35 dB			

Table 1 - TOPEX Altimeter AGC Calibration Table

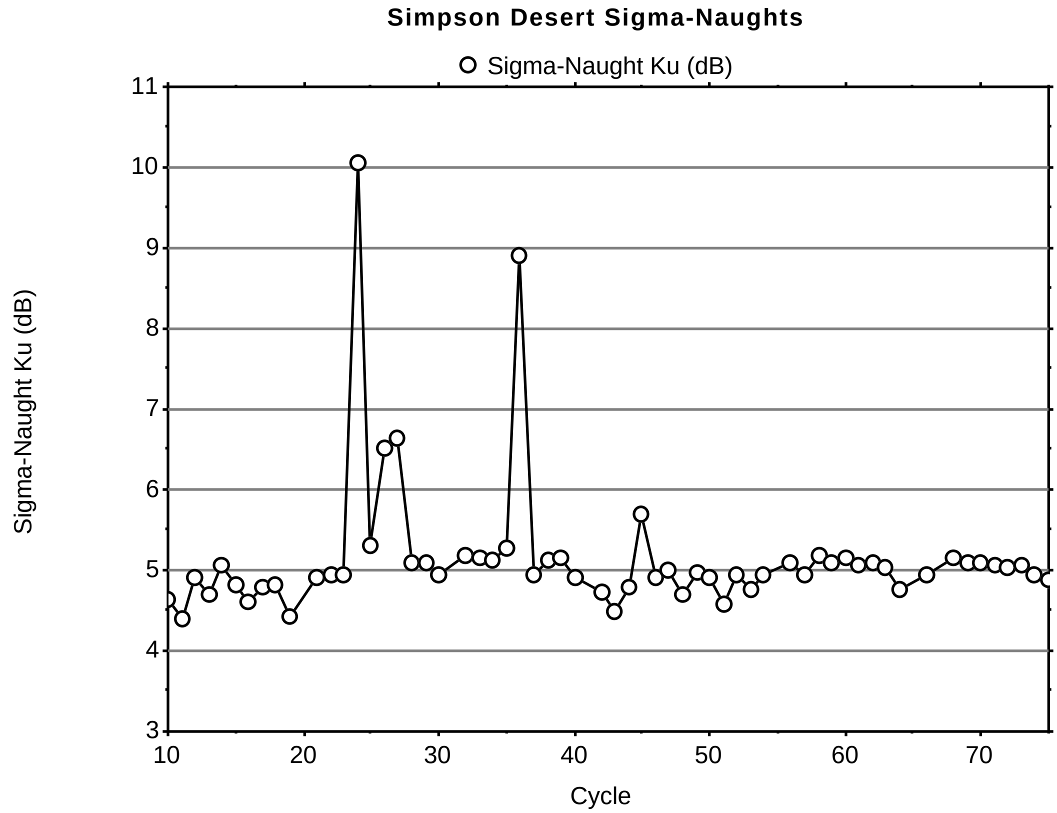

Figure 2 - Ku-Band Sigma-Naught Averages per Cycle

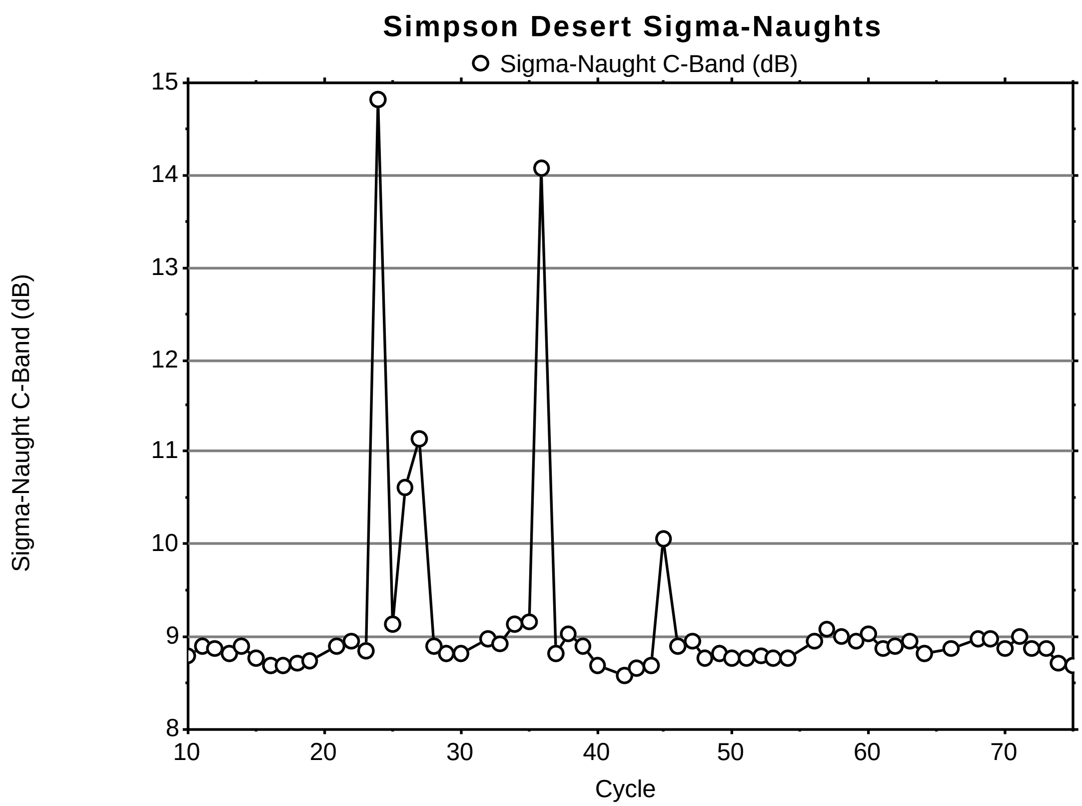

Figure 3 - C-Band Sigma-Naught Averages per Cycle

cycles have essentially the same pattern with respect to latitude as the other cycles, but the values are larger. These anomalies are attributed to terrain brightness changes rather than an altimeter error since the altimeter's over-ocean σ^0 north and south of Australia are normal for these passes.

We suspected that the σ^0 changes were due to increased soil moisture during those five overflights. With the assistance of Drs. Chris Fandry and John Reid of CSIRO / Australia, we were able to confirm our suspicions. Fandry and Reid furnished us with rainfall measurements per day for two sites: the nearest meteorological station, at Birdsville (latitude 25.90S, longitude 139.30E) and for Glengyle (latitude 24.80S, longitude 139.60E). Birdsville is a small (population 100) community on the eastern edge of the Simpson Desert, 290 km east-southeast of the mid-point of our σ^0 averaging area. Glengyle, an even smaller town, is about 310 km east of the averaging area.

The correlations between the σ^0 anomalies over the Simpson Desert with the measured rainfall at the two meteorological stations are good. The better correlation is shown in Figure 4 where recorded rainfall amounts at Birdsville in the 24-hour period prior to each altimeter overflight are depicted, in relationship to the σ^0 values.

The rainfall amounts in centimeters, at the bottom of Figure 4, appear to account for the σ^0 anomalies through Cycle 36. Since that time, however, there has been a small σ^0 anomaly observed during Cycle 45 in this area; neither Birdsville or Glengyle recorded rain. In addition, Birdsville recorded rain just prior to Cycle 43, but the altimeter σ^0 does not indicate bright terrain. Since Glengyle did not record rain prior to Cycle

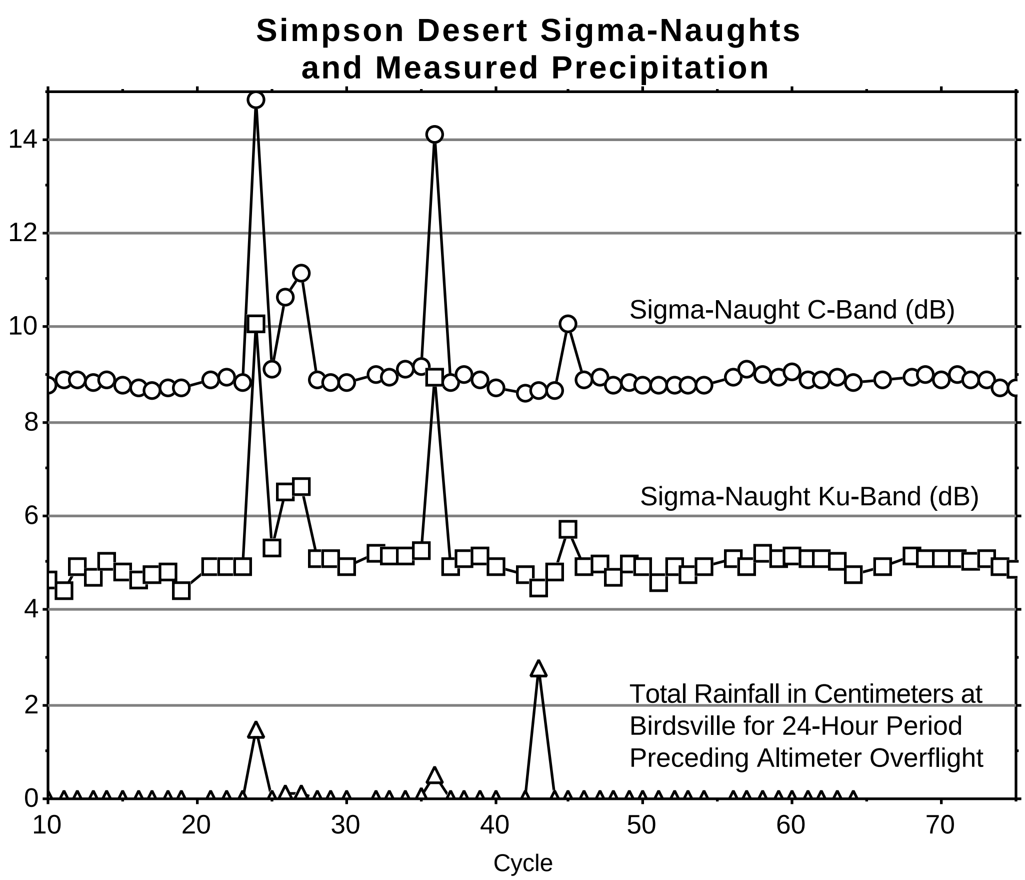

Figure 4 - Ku and C-Band Sigma Naught Averages per Cycle and Measured Precipitation on at Birdsville

43, it is presumed that the Birdsville rainfall was localized. We do not have rainfall data past Cycle 63.

4.0 Conclusions

From Cycle 10 through Cycle 75, C-Band σ^0 (except for the anomalies in five of the cycles) have remained within a fairly narrow band of 8.8+0.3 dB. This peak difference variation is equal to about one LSB in the AGC measurements.

From Cycle 10 through Cycle 75, Ku-Band σ^0 (except for the anomalies) have remained in a broader band of 4.8+0.5 dB. This variation is equivalent to two LSBs in AGC, and is believed to be the result of the Ku-Band's shorter wavelength being more sensitive than C-Band to pass-to-pass terrain differences within the 2 km repeating groundtrack band.

The Simpson Desert, while not an ideal σ^0 calibration area due to sporadic precipitation, is suitable for the purpose. Our conclusion, after accounting for what we believe are soil-moisture-induced surface brightness anomalies and after applying calibration-based corrections, is that there are no significant residual drifts in the altimeter's σ^0 in this desert area.

5.0 Reference

Vessels, J., 1992, The Simpson Outback, *National Geographic*, Vol. 181, No. 4.